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# The design and construction of masonry water supply tanks

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Bulletin No. 302

BY HENRY GIESE AND J. BROWNLEE DAVIDSON

R. M. HUGHES, Acting Director

AGRICULTURAL ENGINEERING SECTION



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## SUMMARY

The elevated storage tank or reservoir offers advantages because it provides a reserve supply of water which is quickly available and also because it is adapted to intermittent wind-mill pumping. Farm fires constitute a serious economic problem, and the losses therefrom may be reduced with adequate water supply on the farm.

The masonry silo provides a desirable support for an elevated water supply tank.

Masonry tanks will, if properly designed and carefully constructed, give long and satisfactory service.

Block tanks must be lined with a waterproofing material which is plastic and of sufficient thickness to remain intact, notwithstanding expansion and contraction of the walls.

Considering low winter temperatures in Iowa, exposed tanks and supply pipes leading to them should be well insulated.

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# The Design and Construction of Masonry Water Supply Tanks<sup>1</sup>

BY HENRY GIESE AND J. BROWNLIE DAVIDSON

## IMPORTANCE OF FARM WATER SUPPLY SYSTEMS

A satisfactory farm water supply system is obviously the most important of the various farm utilities, a term intended to include the heating, lighting, water supply and waste disposal systems of the farm. The distribution of water by underground pipes to the home and to other points of consumption about the farmstead saves much labor, makes the installation of sanitary equipment in the home practicable and furnishes a means of fighting fires. Farm women almost universally place "running water" as the most desired of the modern conveniences. An adequate supply of good water readily available is an important influence in profitable livestock production. Success in fighting farm fires depends almost wholly upon having facilities available to extinguish fires during the incipient stage. Some form of water storage is almost an essential feature of a water supply system although the amount of storage may vary much with the kind of power used for pumping and the amount of water used. Electric power, instantly available for pumping, reduces the amount of storage required. On a few farms, compressed air has been stored for instant use in pumping, reducing the need for water storage. For fighting fires effectively, water storage is almost an essential.

<sup>1</sup>Project 7, 7a, 7b of the Iowa Agricultural Experiment Station.



Fig. 1. An underground cistern.



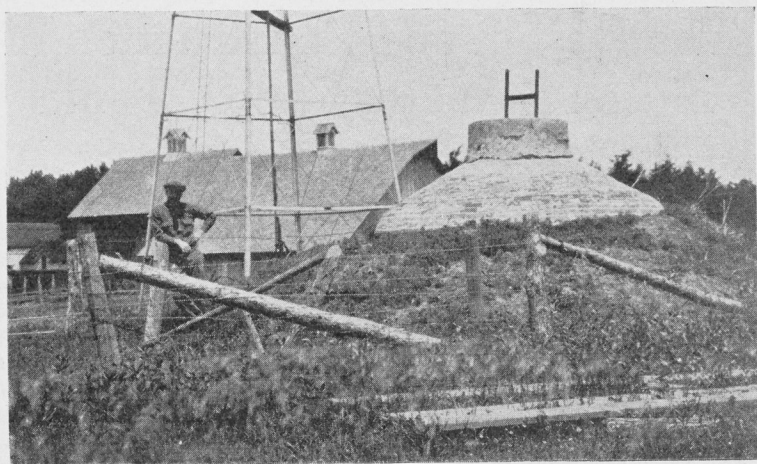


Fig. 2. Cistern with top exposed.

Water storage may be accomplished either by the use of an air pressure tank in which entrapped air under pressure partially fills the tank and drives the water from it as the water is released, or by employing an elevated tank so placed that water from it may be distributed where needed by gravity. The air pressure tank may be placed in the ground, basement or other protected place away from heat and cold. Where the quantity of water to be stored is large, however, as may be the case on

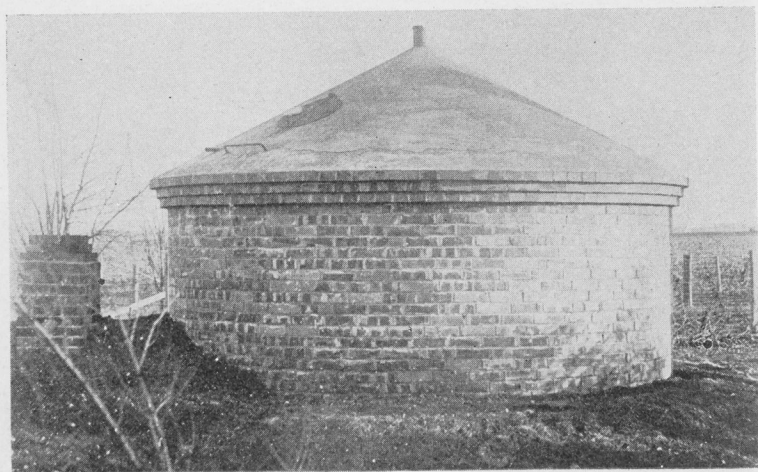


Fig. 3. Storage tank partly above ground.

a stock farm with intermittent power for pumping, the cost of such a tank of adequate size will be excessive.

The elevated water tank is particularly adapted to conditions where the quantity of water stored is large.

#### THE ELEVATED SUPPLY TANK

This discussion will deal entirely with the elevated or gravity tank, the requirements of such tanks and some methods of constructing them, based upon the experiences of the experiment station.

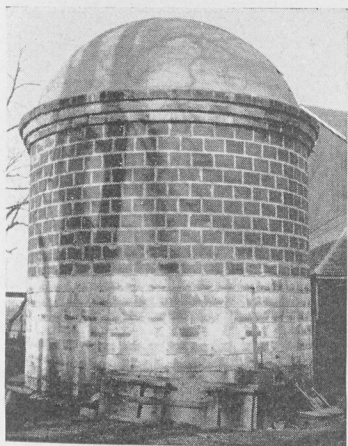


Fig. 4. Supply tank at ground level.

farmstead is located on a hillside, it may be possible to find a place near the house high enough so that the tank may be placed on the ground. It may even be placed in the ground in which case, difficulties resulting from freezing temperatures are greatly reduced. Examples of tanks thus located are shown in figs. 1, 2, 3 and 4. When elevation above the ground is necessary to secure the desired fall and pressure, various methods may be employed. Little elevation is necessary to force water to stock tanks. For fire protection, however, the tank should be well above the tallest structure.

In fig. 5 a wooden tank is placed on a slight elevation and

The elevated tank has been popular with Iowa farmers. If sufficient capacity is provided to carry over periods of calm it is well adapted to intermittent windmill pumping. Large quantities of water are instantly available with little decrease in pressure as long as any water remains in the tank, making it valuable in fighting fires.

The construction and location of this type of tank may be greatly influenced by the topography of the farm. If the



Fig. 5. Wood tank on low concrete block base.

supported by a concrete block wall. When this type of construction is employed, the space under the tank may be used as a milk house or a stock tank (fig. 6). The tank in fig. 7 is elevated somewhat and supported upon a low wooden tower.

### EXPERIMENTS ON CLAY BLOCK TANKS

Shortly after the development of the clay block or "Iowa Silo,"<sup>2</sup> the designers conceived the idea of using these silos as towers for supporting farm water supply tanks. When the silo serves such a dual purpose, it saves the cost of a special tower. A research project was organized in 1910 to design a masonry tank which might be constructed using the Iowa silo as a tower. The first part of this bulletin

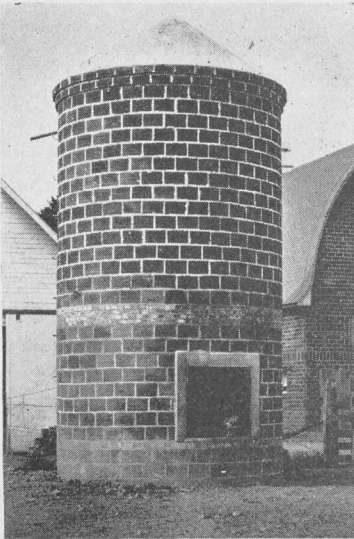


Fig. 6. Supply tank support used for stock water tank.

deals with the experiences in connection with the original design and with the observations and alterations made by subsequent workers.

While almost any kind of tank could be used on these silos, there were some apparent advantages in one which could be built readily by the silo crew and from the materials used in the silo.

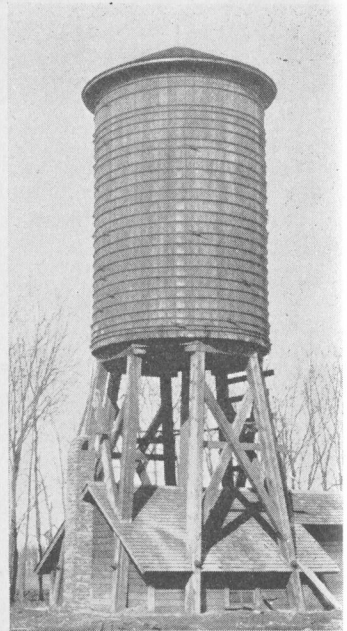


Fig. 7. Wood tank on wood tower.

<sup>2</sup>Davidson, J. B., and King, M. L., Modern Silo Construction. Iowa Agr. Exp. Sta., Bul. 100: 144. 1908.

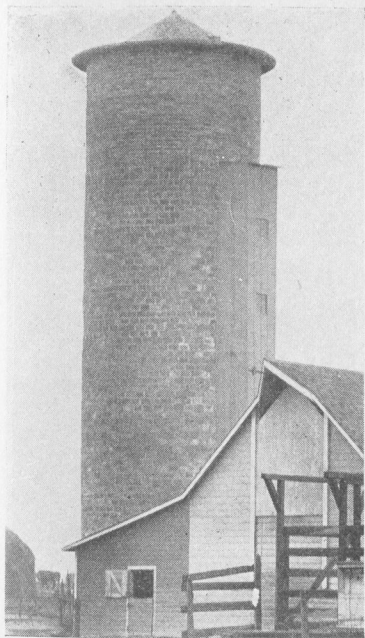


Fig. 8. Experimental tank at Pocahontas, Iowa.

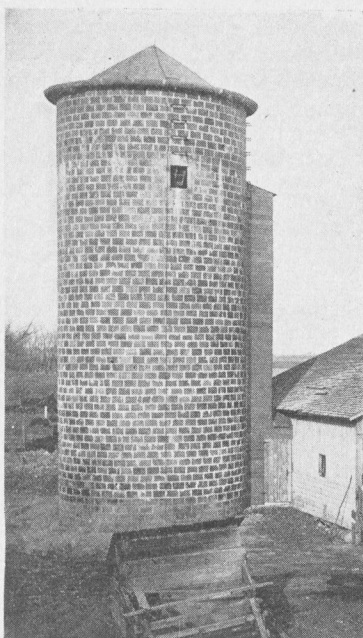


Fig. 9. Experimental tank at Glidden, Iowa.

#### CONSTRUCTION OF EXPERIMENTAL TANKS

During the summer of 1910, two such water tanks were constructed. The first, of 18,000 gallons capacity and supported by an 18x54-foot silo with a 5-inch wall, was located on the county farm of Pocahontas County (fig. 8). The other tank of 6,000 gallons capacity, supported on a 16x35-foot silo with a 4-inch wall, was located on the C. H. Hall farm near Glidden (fig. 9).

A third tank was built in 1912 on the W. C. Whiting farm near Whiting (fig. 10). This was of approximately 13,500 gallons capacity and placed on a 16x40-foot silo. The construction of these tanks as finally developed is illustrated in fig. 11; it consisted first of an outer shell which was simply a continuation of the silo. Tiles were broken away on the inside of the silo so that the concrete floor of the tank could be supported by the silo wall but show no evidence on the outside. A conical shaped floor permitted the use of the same forms as were used in the construction of the roof. The tank proper was constructed independently of the outer wall. To permit the use of more reinforcement to resist the hydraulic pressure,



the lower courses of tile were laid flat. The interior wall was covered with about  $\frac{1}{2}$  inch of cement plaster.

### THE POCAHONTAS TANK

Some difficulties were encountered with the Pocahontas tank during the first winter which was rather severe. During the first cold weather a cake of ice approximately 22 inches thick formed on the surface of the water near the top of the tank. Later on a warm day, when the tank was about half full of water, the ice was released by thawing around the edges and fell, causing severe water hammer. No apparent damage to the tank resulted.

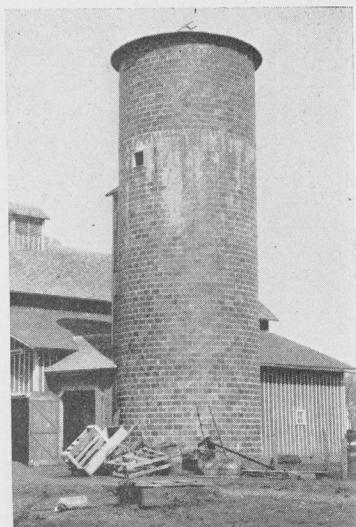


Fig. 10. Experimental tank at Whiting, Iowa.

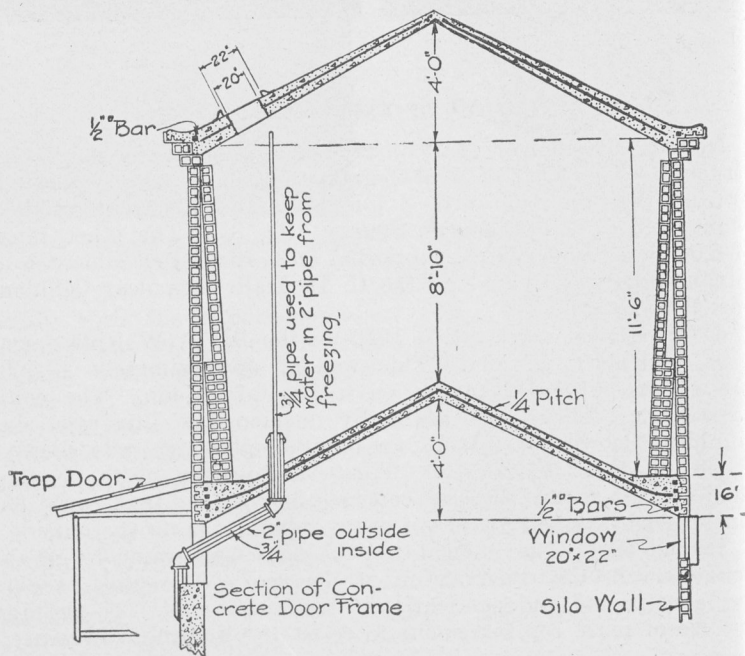


Fig. 11. Construction of original tanks.

During the cold weather in January, water was allowed to stand in the pipes with the result that the water in the supply pipe froze at the point of entrance to the tank. In February, 1911, a heavy coating of ice, varying from 8 to 12 inches thick, extending from the roof of the tank down, formed around the inside of the wall. The tank seemed to be in excellent condition except for a slight seepage. The ice in forming had crushed, showing that the tensile strength of the wall was sufficient to withstand the expanding force of the ice. During the winter of 1911-12, the water in the supply pipe froze once at the point where the pipe entered the tank bottom.

A report made in April, 1914, by W. G. Kaiser states that the tank was leaking badly. The inside of the silo was wet and the outside showed large streaks caused by the leaking water. The plaster coating was rough and badly cracked. The majority of the cracks ran horizontally and seemed to follow mortar joints around the wall. The largest one occurred at a line about 1 foot from the top. Since there were about 4 feet of water in the tank, it was not possible to observe the condition near the bottom on the inside. The presence of water and the poor condition of the clay block wall showed from the outside that a large part of the leakage came from the sides near the bottom. The blocks at the base of the tank and extending entirely around the tank in a belt two tiles wide, were spalling off and gave a dead sound when tapped.

#### THE GLIDDEN TANK

The supply pipe in the Glidden tank also gave trouble during the winter of 1911-12 by freezing at the point where the pipe entered the tank bottom.

At the time of the 1914 report the Glidden tank was dry on the outside. A few damp spots showed at the bottom and near places where there had evidently been some attempt made at waterproofing. There were a few holes in the plaster where small pieces had popped out due to further hydration of the lime, and a line of exposed asphalt spots showed upon almost the entire circumference on the inside of the tank about 20 inches up from the bottom. The report indicates that the combined thickness of both the plaster and asphalt appeared to be less than  $\frac{1}{4}$  inch. This proved insufficient. The plaster and asphalt layers applied to the roof peeled off, apparently due to the weight of ice freezing to the plaster.

In the fall of the same year when Mr. Kaiser undertook to repair the tank at Glidden, it was leaking badly through cracks evidently produced by unequal expansion and contraction of the materials. Water that had seeped or condensed between the two walls froze, breaking a number of blocks in the outside wall. The tank was cleaned and defective blocks replaced.



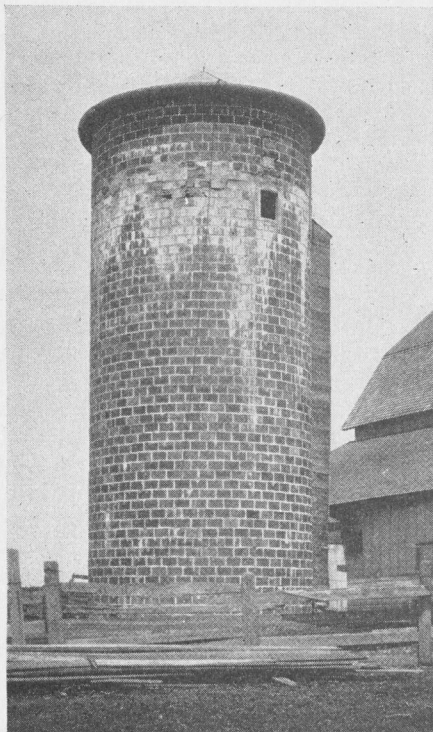


Fig. 12. Glidden tank showing deterioration.

Over a 3/16-inch layer of asphalt mastic, two coats of cement plaster were applied, each approximately  $\frac{1}{4}$  inch thick and consisting of 1 part lime, 4 parts cement and 8 parts of fine sand.

A careful examination of the tank about a month later showed only one damp spot about 2 inches square at the intersection of a horizontal and vertical mortar joint about 2 feet above the bottom of the tank. The plaster coat lining was smooth, hard and without cracks.

A report made during 1916 states that the tank leaked a little during February and March when wide temperature fluctuations were frequent. Other reports received up to March, 1920, state that the tank was giving satisfaction

with no further trouble than the occasional freezing of the supply pipe during cold weather.

In October, 1922, J. B. Davidson and W. A. Foster reported the tank in poor condition and disuse. The plaster had separated from the asphalt mastic and sluffed off from the roof. Mastic had flowed through cracks in the plaster side walls, but the plaster otherwise was still intact. The outside blocks were in bad condition.

#### THE WHITING TANK

In 1914 the Whiting tank was leaking in places near the bottom. A layer of asphalt applied to the plaster in this tank was so thin in some places near the top as to expose the wall underneath and had peeled off entirely from the lower half of the tank. Rust on the asphalt indicated that the wall had not been thoroughly cleaned before the asphalt was applied. There was a crack about  $2\frac{1}{2}$  feet from the top of the tank which extended entirely around it. Both this tank and the

one at Pocahontas showed clearly that the roof and inner wall had not expanded and contracted equally with temperature changes.

In June, 1915, when Bert R. Mullen inspected the Whiting tank, it contained about 20 inches of water and 6 inches of sand, sticks and tar waterproofing. Near the top of the tank, the old tar waterproofing was still clinging to the wall. The bottom 20 inches showed no signs of the original asphalt having been applied.

The water and dirt were removed and the wall scraped with putty knives, washed and brushed with a wire brush. The plaster showed a number of cracks, particularly about 18 inches from the bottom of the tank and approximately the same distance from the top. These cracks extended nearly around the inside of the tank.

After cleaning and drying the wall, a priming coat of asphalt mastic thinned with gasoline was applied to the wall and floor. For a second coat, the mastic was heated until well melted and then applied. Care was taken to give portions of the wall in which cracks were visible, an extra thick coating. The main wall and floor were covered to a thickness of about  $3/16$  inch.

Two coats of cement plaster mixed in the proportion of  $1\frac{1}{2}$  parts cement to 1 part sand were plastered on the wall, and one coat was applied to the floor of the tank.

Other reports up to 1925 state that the tank gave little further trouble than the occasional freezing of the water in the supply pipe.

A few of the blocks in the outside wall near the bottom of the tank showed evidence of deterioration. By June, 1926, however, the appearance changed considerably. The water leaking through the tank wall or that condensing between the walls had frozen and damaged the outer layers of tile near the bottom of the tank (figs. 13 and 14). In two or three instances the outer shell of the tile was entirely destroyed. Most of the tile in the courses mentioned showed some evidence of deterioration.

The pipe from the tank to the ground was located on the north side. It was a 2-inch supply pipe surrounded by a 4-inch pipe, which in turn was covered with an insulation of hair and asbestos. The 4-inch pipe provided an air space around the 2-inch supply pipe and also permitted hanging a lantern at the lower end and thawing in case freezing did occur. Failure to protect the insulation from the weather resulted in saturation in places and a reduction in the insulating value. When the insulation was wet it sagged, leaving exposed joints. Freezing occurred frequently during cold weather.

The pipe was moved to the south side; the 4-inch pipe discarded and a  $3/8$ -inch pipe was placed inside of the 2-inch supply

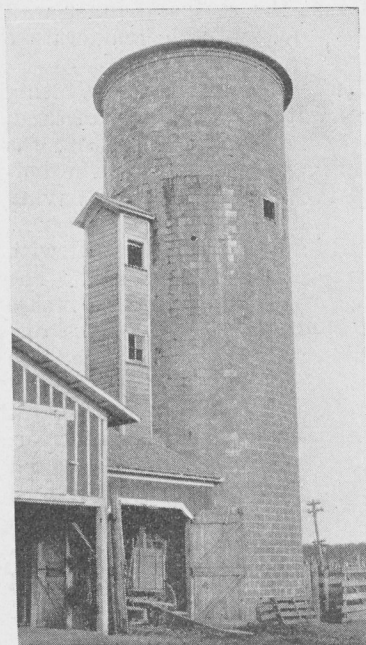


Fig. 13. Whiting tank in bad order.

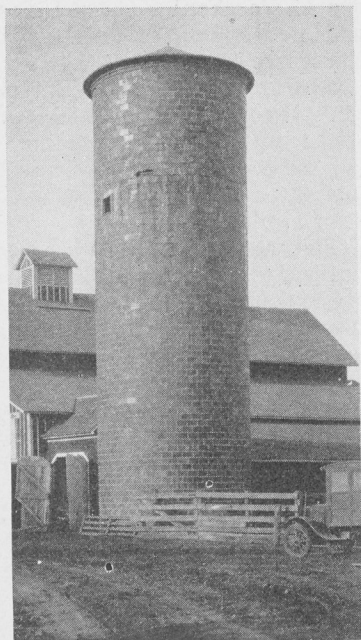


Fig. 14. Another view of the Whiting tank.

pipe. This was insulated with special brine thickness Non-pareil cork covering, as manufactured by the Armstrong Cork and Insulation Company.

Because the tank showed considerable disintegration on the outside, a 12x8-foot wooded tank was placed on the inside, and the masonry tank has since served only as a housing. At the time this was done, a hole approximately 2 feet square was cut through the tank wall and outer wall just above the floor of the tank. After spending nearly a day in cutting this small hole it was decided that the tank was in much better condition than was apparent from the outside. With a little attention to waterproofing and the improvement of some constructional details, it would have lasted indefinitely. The cork pipe covering has given very satisfactory service.

#### OTHER CLAY BLOCK TANKS

In addition to making tests on the above tanks, observations have been made on others. In figs. 15 and 16 are shown two tanks which have fallen into disuse because of inadequate insulation. No insulation was provided either in the tank walls or in the supply pipes. As a consequence the water in the pipes

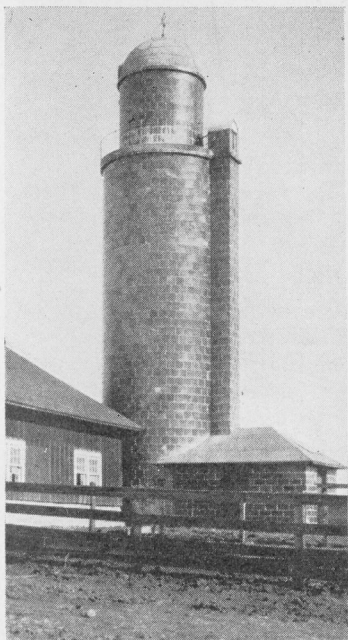


Fig. 15. Tank at Lisbon, Iowa.

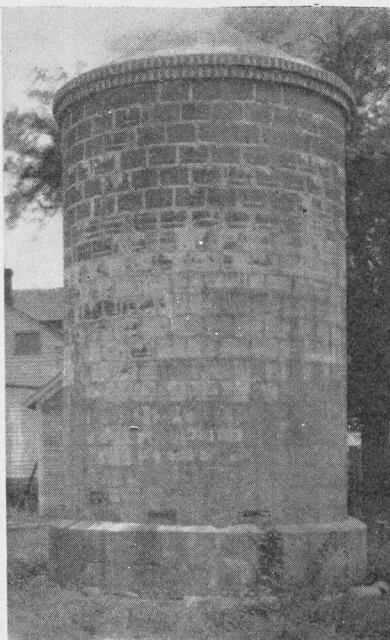


Fig. 16. Tank near Muscatine, Iowa.

froze at the outset of cold weather. Since no water could flow through the pipes, all the water in the tanks froze, eventually disintegrating the tile as can readily be seen in the photographs. Thus good specimens of masonry construction become ineffective because of the lack of attention to a few details. Figure 15 shows a modification of the original plan in that the tank proper

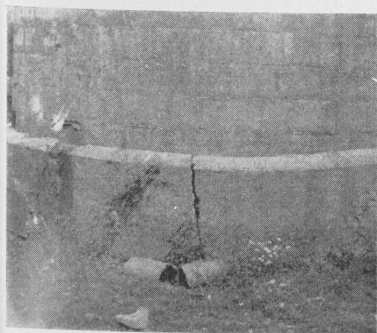


Fig. 17 Tank with cracked foundation.

is somewhat smaller than the silo. With the Whiting tank it was difficult to place the silage cutter pipe in the door at the top of the silo because there was no safe place for a workman while placing the pipe. If the tank is made smaller than the silo, this difficulty is obviated and repairs or alterations can also be made more easily.

Careful attention should be given to foundations. Figure 17 shows a tank built



on the ground. The cracked foundation doubtless resulted from the fact that it did not extend into the ground below the frost line.

### PROBLEMS IN MASONRY TANK DESIGN

In the following pages we shall endeavor to apply these experiences with the experimental tanks to the design and construction of water supply tanks suitable for farm use. Some problems common and applicable to any material selected will be discussed first.

#### SIZE OF TANK

The size of tank necessary to assure an adequate supply of water at all times should be determined first. This should be governed by the water requirements of the family and the farm animals, the amount needed to assure fire protection and the character of the source of supply.

Farm fire protection is a serious economic problem. Because of lack of protection, farm fires frequently result in total loss. A small stream of water, if well directed and applied before the fire gains headway, may be the means of preventing large losses. Fire departments are handicapped in fighting farm fires because of distance and the uncertainty of highways. Even when they can arrive at the fire in ample time, their effectiveness may be limited by the water supply.

The farm fire protection committee of the National Fire Protection Association has recommended that where no natural supply of water is available there should be at least an underground tank. Elevated tanks which are a part of the water system may be used. A  $\frac{1}{2}$ -inch nozzle commonly used by rural fire departments will throw about 50 gallons of water per minute. A 3,000-gallon tank would provide 1 hour's supply. Since practice shows that tanks are usually maintained to only three-fourths capacity, a tank holding 4,000 gallons is recommended.

If for any reason the source of supply is limited or variable, the size of tank should be further increased. Table II shows the capacities in gallons of cylindrical tanks of various sizes.

#### WATER PRESSURE

The water pressure at an outlet in a water supply system varies directly with the elevation of the water in the storage tank above the outlet. A difference of 1 foot in elevation pro-

TABLE I. FARM WATER REQUIREMENTS (GALS.)

Daily range		Average
Horse	7 to 10-----	8
Cow	6 to 12-----	9
Hog	2 to 3-----	$2\frac{1}{2}$
Sheep	1 to 2-----	$1\frac{1}{2}$
Person—25 to 50 gallons per day including that used for dish washing, bathing, etc.		
Allowance should be made for other uses.		

TABLE II. CAPACITY OF CYLINDRICAL TANKS—GALLONS

Depth in feet	Diameter in feet				
	8	10	12	14	16
4-----	1,190	2,350	3,385	4,605	6,015
6-----	1,785	3,525	5,075	6,910	9,025
8-----	2,380	4,700	6,765	9,210	12,030
10-----	2,970	5,875	8,460	11,515	15,040
12-----	3,565	7,050	10,150	13,820	18,050
14-----	4,160	8,225	11,845	16,120	21,060

duces a static pressure of 0.433 pound per square inch. The flow of water varies with the pressure, and the resistance due to size of outlet and friction in the pipes. The strength of the tank walls must be designed also to resist the bursting pressure due to the water in the tank, and the floor and tower must be constructed with sufficient strength to support the weight of the tank full of water.

The elevation of the tank may be determined by the facilities available. If a silo is used as a tower the height of the tank is determined thereby.

The static pressure at the hydrant is directly proportional to the difference in elevation between the hydrant and surface of the water in the tank.

Table III shows the static pressure of water for different heights.

TABLE III. STATIC PRESSURE OF WATER FOR DIFFERENT HEIGHTS

Height in feet-----	15	20	25	30	35	40	45	50
Pressure lbs. per sq. in.-----	6.50	8.66	10.83	12.99	15.16	17.32	19.49	21.65

The rate at which water will flow depends upon this water pressure and upon the size and length of the pipe from the tank to the hydrant. This pipe should be not less than 1½ inches and preferably 2 inches in diameter.

The same pressure which causes water to flow through the pipes when the hydrant is opened also tends to burst the tank. One should remember that this pressure is much greater than that ordinarily caused by silage. The pressure of corn silage approximates 11 pounds per foot for each foot of depth. Water pressure, on the other hand, is about 62.4 pounds per square foot for each foot of depth. This difference necessitates much heavier reinforcing for tanks than is used in silos of the same size.

In masonry tanks, this bursting pressure is carried by steel reinforcement. The amount of steel required increases from the top to the bottom as the water pressure increases.



The following formula is used in determining the necessary cross sectional area of steel bars to be placed in the mortar joints of clay block tanks or located at proper intervals in the monolithic concrete tanks.

$$A_n = \frac{62.4 \text{ HD}}{2f_s}$$

Where  $A_n$  is the area of steel in square inches per foot of height at the section considered,

H is the height in feet of water above the section considered,

D is the diameter of the tank in feet,

$f_s$  is the allowable stress per square inch of steel and is usually taken at from 12,000 to 16,000 pounds.

62.4 is the weight of a cubic foot of water in pounds.

From fig. 18 one can determine the number of No. 3 wires necessary for clay block tanks using either 8-inch or 12-inch blocks. It will be noted that in the larger tank sizes so many wires are required for the 12-inch tile that their use becomes questionable. On the other hand, brick (fig. 19) with more joints per foot requires less reinforcing per joint.

#### ROOF AND FLOOR SLAB CONSTRUCTION

A conical roof was used with the original Iowa silo. Since forms were already on the job for constructing this type of roof, the investigators felt the desirability of using the same construction for the tank floor. The conical roof and floor construction, although requiring some additional labor and material

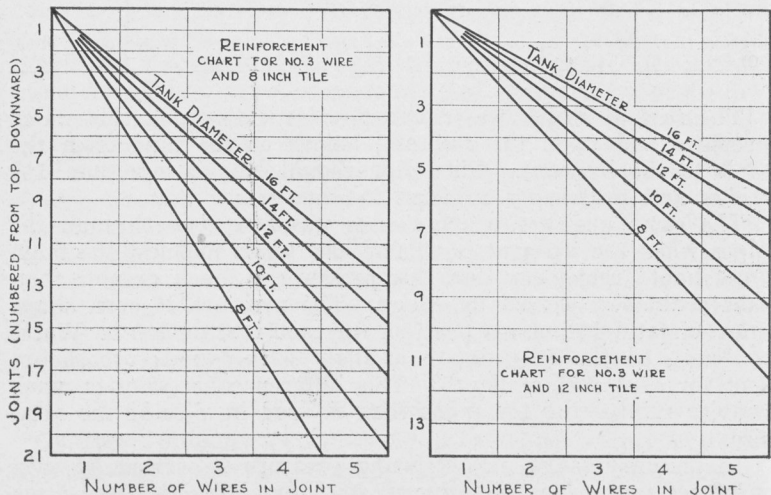


Fig. 18. Reinforcing schedule—tile walls.

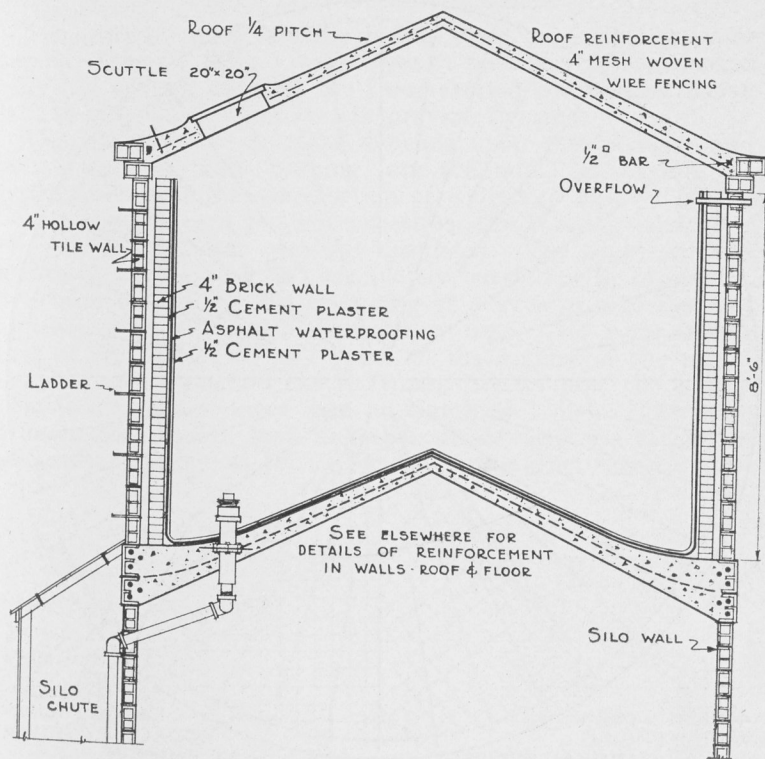


Fig. 19. Brick walled tank construction.

for centering, is well adapted by form to carry heavy loads, and the amount of reinforcement required is small compared with that needed for flat construction. With the exception of a limited amount of steel to resist shear in the roof proper, the major portion of the reinforcement may be placed in the base of the cone in the form of continuous hoops or circles. A tank floor obviously requires more strength than a roof, although many conical concrete roofs have been built sufficiently strong for a tank floor if additional reinforcements were added at the base of the cone. This conical shape also has made possible the construction of tanks on top of silos already built. The design of this roof is shown in fig. 20, and the method of construction is illustrated in fig. 21. Recently a hemispherical roof made with brick or special roofing tile has been popular (figs. 4 and 25). The design of a flat slab for this purpose may be found in fig. 28.

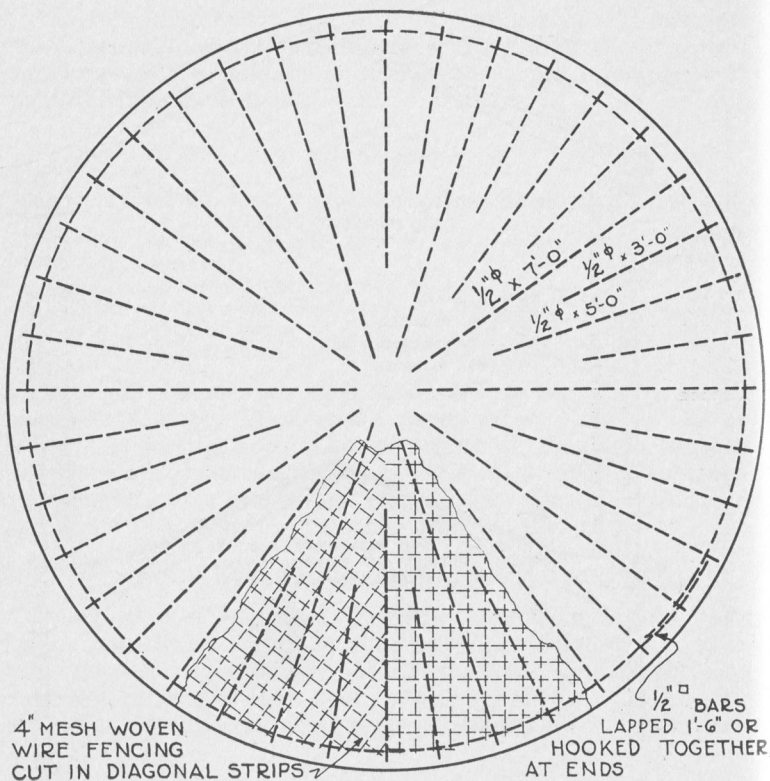


Fig. 20. Reinforcing of conical floor.

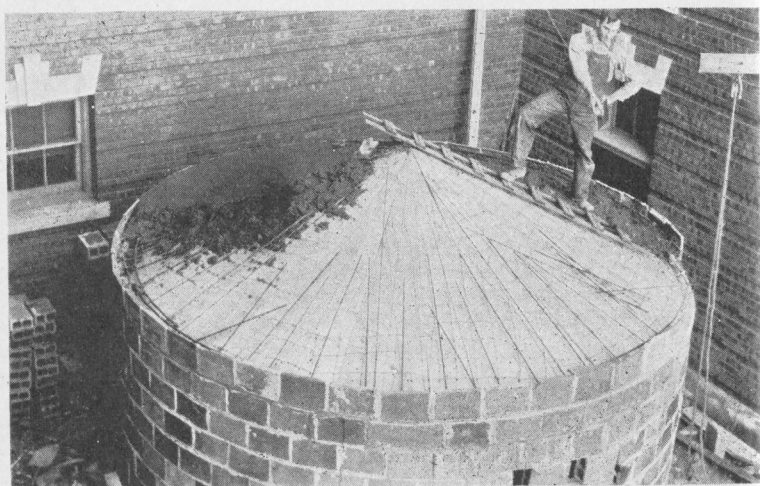


Fig. 21. Construction of conical roof.

## HEAT LOSS AND INSULATION

The prevention of freezing is important in designing water supply tanks for Iowa. Some types of tank may be constructed ruggedly enough to resist the force exerted by freezing water, but, in general, it seems best to prevent freezing.

The likelihood of freezing depends upon the quantity and temperature of water coming into the tank, the outside air temperature and the construction of walls and roof. The following experience is related concerning the Whiting tank after the supply pipe was carefully insulated. The tank with the exception of the roof was completely covered with insulation. The tank was full at the beginning of a week of zero weather, and no water was added during that time. Not more than 1 inch of ice formed at any point on the surface of the water. Only on rare occasions has it frozen directly over the supply pipe to a thickness more than an eighth of 1 inch. The space between the wooden tank and the outside shell has reached a temperature as low as 16° F. but only for a short time.

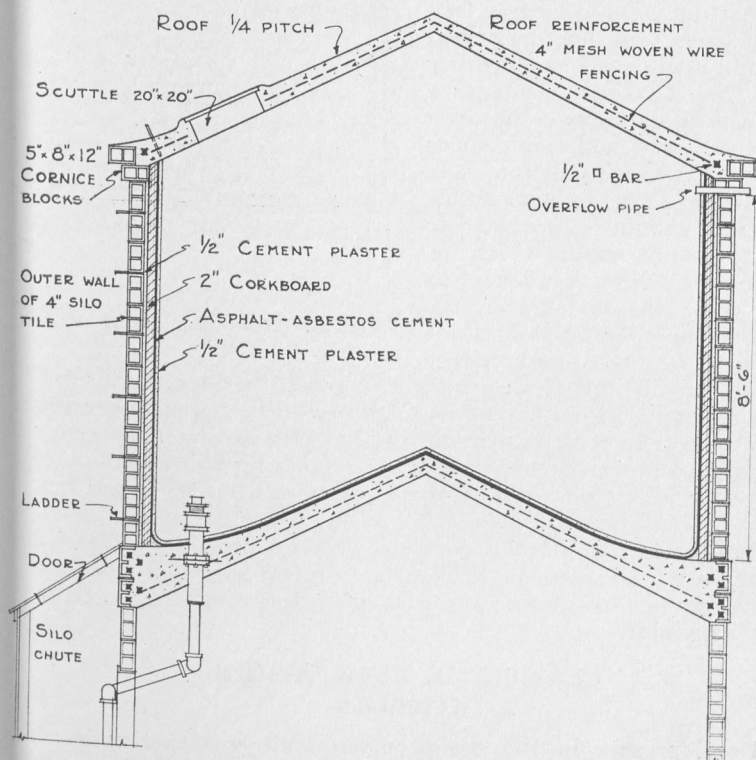


Fig. 22. Tank lined with cork insulation.



Tanks constructed with single walls only may prove satisfactory in climates mild enough that freezing does not become a problem. Clay block tanks built above ground in Iowa should be insulated. Insulation may be accomplished by the construction of a double-walled tank, as mentioned in the preceding paragraph, or by the application of an insulating material to the single wall as indicated in fig. 22. Waterproofness is an essential characteristic. Insulating materials derive their value from many air-filled spaces. If this air is replaced with water, the insulating value is largely lost. A wooden tank may be placed inside a tile shell as shown in fig. 23. In some instances a tank is used of such a diameter as to leave sufficient space around it for inspection.

In double wall construction, a drain should be provided to remove any water which accumulates from condensation or other causes between the walls. The opening should not be large enough to admit free circulation of air as to do so would greatly reduce the insulating effect of the double wall. Care should be taken to prevent the collection of moisture within the cells of any of the clay blocks, as the water expanding upon freezing will disintegrate the tiles. This necessitates good joints on the inside and outside of both walls.

The insulation of the roof as well as the side walls will prove a good investment. The water in an insulated tank will remain cooler in summer and give much less trouble from freezing in winter.

### CLAY BLOCK TANK DESIGN MATERIALS

Developments in tile design make tank construction much simpler and more satisfactory than when the test tanks were

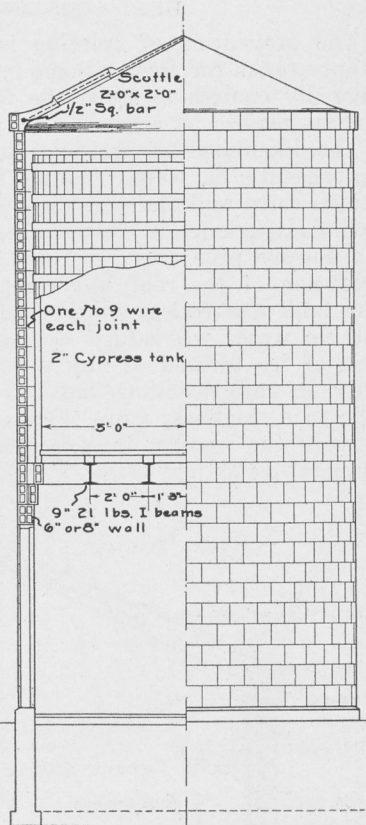


Fig. 23. Wood tank in tile silo shell.

built. The plain single-walled blocks at the left in fig. 24 made tight walled construction difficult. The newer designs shown to the right with thicker walls and openings which provide a key between tile and mortar provide a wall which can be more easily made waterproof.

Care should be taken in the selection of materials to be used in the tank. Hollow tile should be uniform, of proper curvature, free from objectionable cracks and be manufactured in such a manner and burned to such a degree of hardness that it will have an average absorption of not over 7 percent by the 1-hour boiling test and otherwise conform to the American Society for Testing Materials specifications for hollow clay tile<sup>3</sup>.

Hollow clay tile should be set with cement mortar composed by measure of 1 part Portland cement to not more than 3 parts of clean sand, to which may be added hydrated lime not exceeding 15 percent by measure of the cement. The percentage of lime added is always figured on the quantity of the cement used. The lime specified is not needed to strengthen but to make it more plastic and easier to handle. Mortar containing lime will adhere better to the tile, makes a neater job and results in saving in labor. Too much lime must not be used as it weakens the mortar. A straight lime mortar, however rich the mixture, is not suitable for setting the hollow tile. Sand containing any loam must not be used for cement mortar or plaster. Sand containing a little clay may be used if the grains are not coated. Good results cannot be obtained unless blocks are carefully laid and mortar joints well filled.

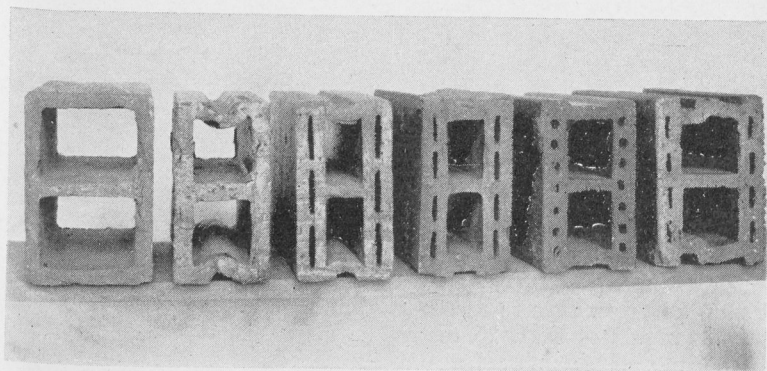


Fig. 24. Development in silo tile design.

<sup>3</sup>Am. Soc. for Testing Mat'ls. St'd. Spec. and tests for hollow burned clay load-bearing wall tile. Serial designation C34-27. A. S. T. M. St'ds. Part II nonmetallic mat'ls. 213-218. 1927.



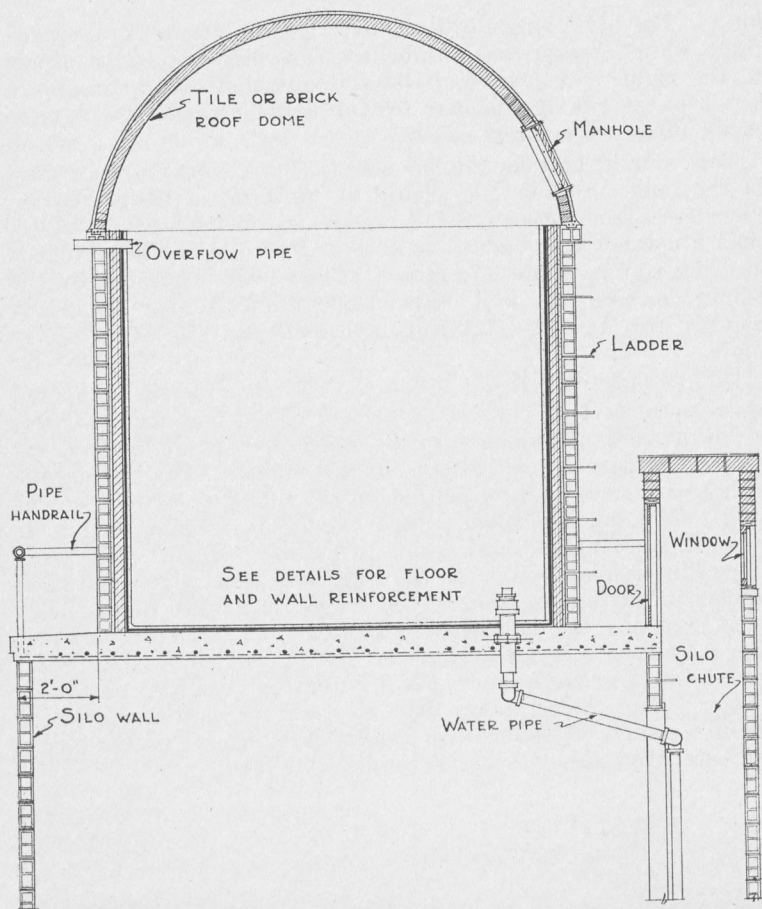


Fig. 25. Design for clay block tank smaller than silo.

### EXPANSION AND CONTRACTION

Masonry materials undergo a considerable change in size when alternately subjected to high and low temperatures. Difficulty has been experienced in tank construction because while the outside wall is exposed to wide variations of temperatures ranging from well below zero to upwards of 100° F., water temperatures may change less than 25 degrees. This variation has resulted in spalling off of tile surfaces and the formation of cracks which permit leakage. For this reason, as well as to secure better insulation, the construction should be such as to make the wall of the tank proper independent of the expansion and contraction of the outside wall. Joints formed between the tank wall and floor should be well caulked with a cement composed of

asbestos fibers ground into asphalt or other material of known quality.

#### WATERPROOFING

The most satisfactory method of waterproofing tried in these experiments consists of an asphalt cement. This is available in consistency of soft putty and will not run nor crack. The layer should be at least  $\frac{1}{8}$  inch thick and preferably  $\frac{3}{16}$  inch as difficulties were experienced due to thin spots. A covering of at least  $\frac{1}{2}$  inch of cement plaster will protect it from abrasion. Some difficulty will be experienced in making this application, but care should be taken to assure that it is done well. The placing of expanded metal or other mesh-reinforcing inside of the asphalt layer, will be of assistance in placing the plaster.

#### CARE AND REPAIR

Clay block tanks should be maintained in good condition. Any imperfections should be repaired promptly.

#### CONCRETE TANK DESIGN

Concrete has given satisfaction in the construction of many masonry supply tanks (fig. 26). The discussion here relates to the selection of materials as well as the design and construction. Tanks may be either of monolithic (cast in place) construction or be made by the assembling of small pre-cast units.

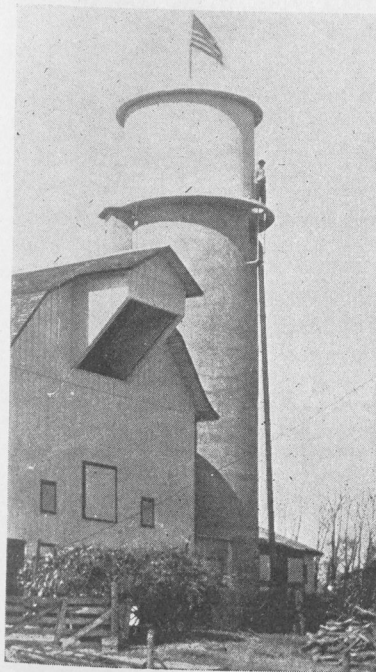


Fig. 26. Monolithic concrete tank.

made by the assembling of small pre-cast units.

#### MONOLITHIC CONSTRUCTION

On account of difficulties encountered in securing or making circular forms, there recently has been a demand for rectangular tanks. Further information regarding this type of tank or on the selection, proportioning, mixing and placing of materials may be secured from the Portland Cement Association<sup>4</sup>. The circular tank offers some advantages in that a minimum length of wall is required to enclose a given volume. Furthermore, since all wall loads are tensile, the wall can be of

<sup>4</sup>Portland Cement Association, Research Division, 33 West Grand avenue, Chicago, Ill.

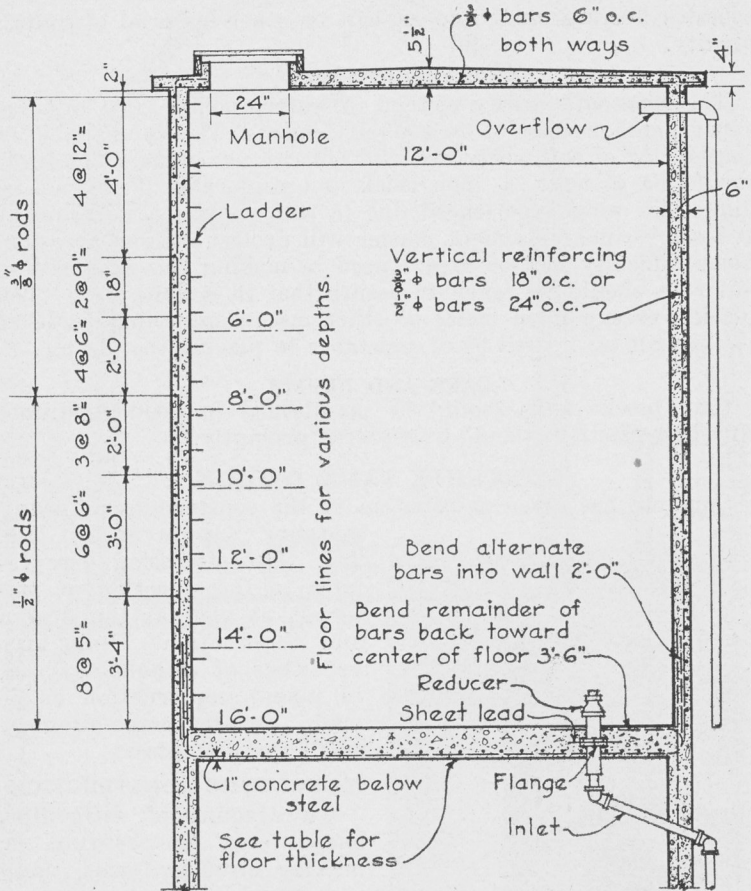


Fig. 27. Reinforcing schedule for monolithic concrete tank.

minimum thickness and steel reinforcing used to resist the bursting pressures.

The discussion relating to pressures and reinforcing of clay block tanks is equally applicable here. The method of placing, however, differs as shown in the accompanying design which is included through the courtesy of the Portland Cement Association.

Figures 27 and 28 show the placing of reinforcing in walls and floor and table IV gives floor thickness and floor reinforcement for tanks 12 feet in diameter and depths up to 16 feet.

Reinforcing steel is located in the outer portion of the wall and in the lower portion of the floor slab, in each case with

TABLE IV. FLOOR THICKNESS AND REINFORCEMENT FOR TANK FLOORS  
(Diameter of tank—12 feet)

Depth of tank	Thickness of floors	Spacing in a, fig. 28	Spacing in b, fig. 28
6-0	7"	7½"	10"
8-0	7½"	6½"	9"
10-0	8½"	6"	9"
12-0	9"	5½"	8"
14-0	9½"	5"	7"
16-0	10"	4½"	6"

not less than 1 inch of concrete between the steel and the wall surface.

To secure dense, watertight concrete<sup>5</sup> necessary for the construction of a leak-proof water tank, the mixture must contain not more than 5½ gallons of water per sack of cement. If the sand and pebbles are moist or wet, the quantity of mixing water should be reduced accordingly. Emphasis should be placed here upon the importance of observing this ratio. Portland cement mixed with water forms a paste. The strength of the paste determines the strength of the concrete. When sand and pebbles are so mixed with this paste that every particle is coated and the spaces between the particles filled, plastic concrete is obtained. This workable mass of cement, water, sand and pebbles, when placed and properly cured, becomes hard like stone.

Strength, watertightness and durability of concrete are controlled by the amount of water used per sack of cement. The inclusion of too much mixing water thins or dilutes the cement paste and weakens its cementing qualities.

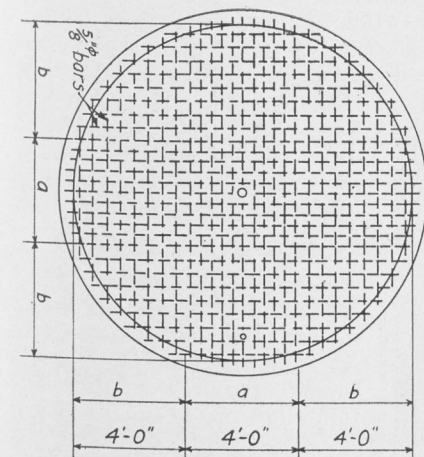


Fig. 28. Reinforcing schedule for concrete floor slab.

As a trial mixture for determining the correct proportions of sand and pebbles for water-tight concrete, 1 sack of cement to 2 cubic feet of sand to 3 cubic feet of pebbles (1-2-3 mix) is recommended.

<sup>5</sup>Design and control of concrete mixtures: Portland Cement Association, Chicago.



## AGGREGATES

Aggregates for concrete should be clean, hard and free from dirt, loam, or vegetable matter and well graded in size. Foreign materials are objectionable because they prevent adhesion between the cement and sand, hard particles of aggregates. Concrete made with aggregate containing loam hardens very slowly at best and may never harden enough to produce a good quality of concrete.

Pebbles, crushed stone, or other coarse aggregates should be tough, hard and free from impurities that are objectionable in sand and also well graded in size. In thin slabs or walls, the largest pieces of aggregate should never exceed one-third the thickness of the section of concrete being placed.

Bank-run gravel, the natural mixture of sand and pebbles as taken from the pit, usually contains more sand than is desirable in a concrete mixture. A more economical concrete will result if the large aggregate content is increased by additions from screenings or from other sources. The coarse aggregate should be at least equal in amount to the sand.

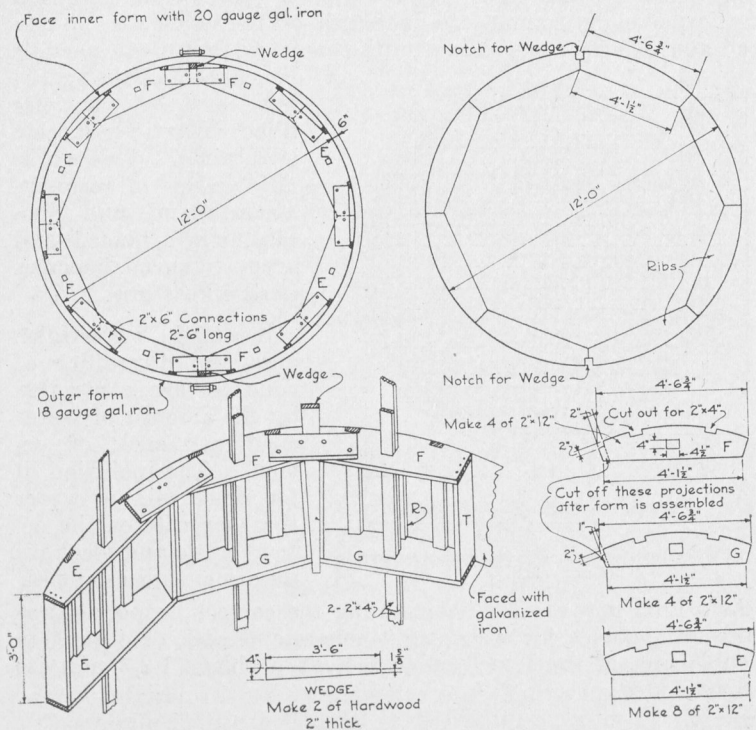


Fig. 29. Forms for casting circular tank.

### WATER

Water used to mix concrete should be clean, free from oil, alkali and acid. In general, water that is fit to drink is suitable for making concrete.

### MIXING AND PLACING

All materials, including water, should be accurately measured for every batch. Mixing, whether by machine or by hand, must proceed until the stones or pebbles are completely coated with a mortar of sand and cement and the mixture has the same color and plasticity throughout.

It should be placed in the forms in 6 to 10-inch layers and thoroughly spaded within 45 minutes after mixing. This operation compacts the concrete, releases air pockets, and works large particles away from the face of the forms.

### CURING

Prompt curing particularly during the first three days is essential to water tightness and for the prevention of shrinkage cracks. Moisture and moderate temperatures are necessary for the proper hardening of concrete. All sections should be protected from drying out by the use of moist canvas or burlap, or by covering with wet straw or earth.

### FORMS

Silo contractors usually have on hand the forms necessary for construction of a water tank. When such forms are not available, homemade forms similar to those shown in the drawing (fig. 29) are suitable. Placing of the forms and proper location of the reinforcing steel are problems requiring careful workmanship.

### CONCRETE STAVE TANKS

The essential difference between the monolithic and the stave tank (fig. 30) lies in the method of placing the reinforcing. Pre-cast staves are held in place by metal hoops. Rules applying to reinforcing will also govern the size and spacing of hoops. Since the staves are usually 2 inches in thickness, much thinner than the corresponding section of the monolithic tank, it is even more essential that great care be taken in making the staves. Good

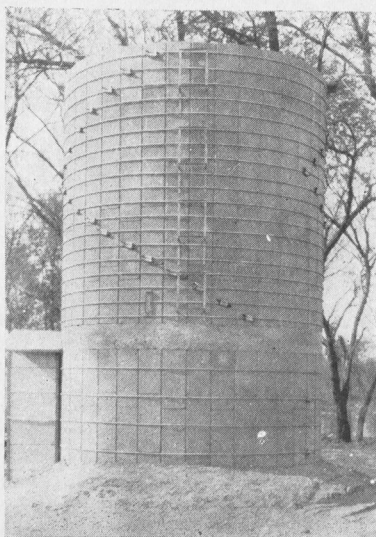


Fig. 30. Concrete stave tank.



materials well proportioned and properly cured will give good results. The floor construction is identical to that used in the monolithic tank.

### CONCRETE BLOCK TANKS

Satisfactory tanks can be made from concrete blocks following the suggestions given above regarding the construction and reinforcement of clay block tanks.

### MISCELLANEOUS DETAILS

#### SUPPLY PIPE

Careful consideration should be given to the pipe leading to the tank. This should be not less than 2 inches inside diameter to permit a rapid flow of water during emergencies.

The insulation of the supply pipe may be a limiting factor in the use of the tank. In fig. 31 is shown the method used in insulating the first of the experimental tanks. This insulation can be applied by any carpenter and will give fairly satisfactory results. Difficulty has

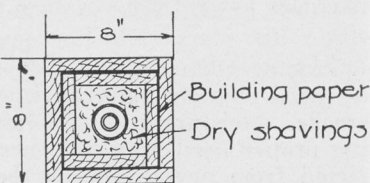


Fig. 31. Pipe insulation detail.

been experienced due to moisture penetration and settling of the shavings. Wood, on becoming wet, loses much of its insulating value. Shavings upon settling leave an uninsulated

space at the top and have permitted the freezing of the water in the pipes. The cost of this method may also run higher than first anticipated. In one tank, this type of insulation was later replaced with a commercial covering of a layer of magnesite over a layer of curled hair. While this material is fairly satisfactory over warm pipes, it has not given good results in the insulation of these cold-water pipes. The materials, on becoming moist, sagged leaving open joints. Sparrows picked out the hair for nests and the unprotected pipe froze. A cork covering with

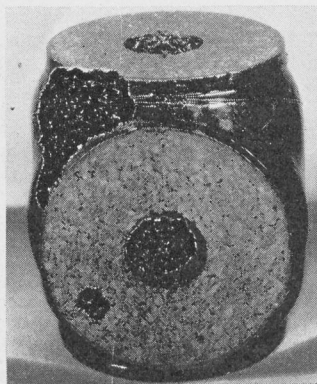


Fig. 32. Cork pipe covering.

molded joints has given satisfaction (fig. 32). The material will not sag leaving open joints. Special shapes protect the pipe fittings equally well with other portions of the pipe. Cork is also highly resistant to the penetration of moisture.

Some of the tanks have been provided with a small pipe inside of the supply pipe to prevent freezing or thawing after

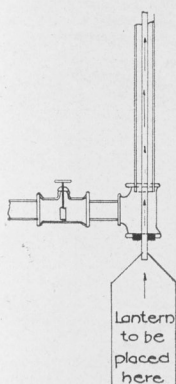


Fig. 33. Lantern arrangement for thawing pipes.

considered good practice to allow the supply pipe to extend a few inches above the tank floor. This allows a settling of the sediment in the water which can be removed by an occasional cleaning.

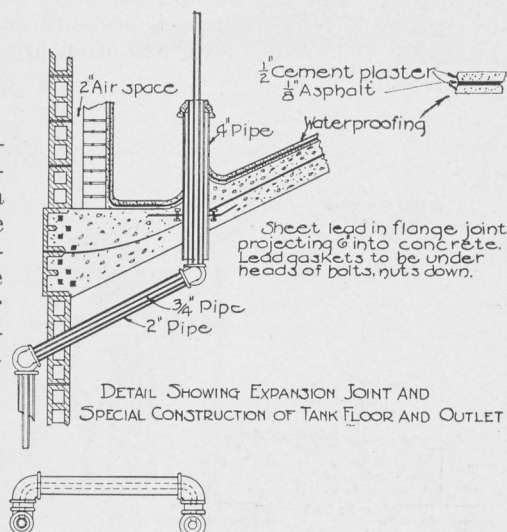
the freezing has once taken place (fig. 33). This, however, is not necessary if the supply pipe is well insulated.

### EXPANSION JOINTS

The expansion and contraction of the supply pipe may be taken care of by using four elbows as shown in fig. 34.

### JOINT BETWEEN PIPE AND TANK

The supply pipe should not come in direct contact with the concrete floor. Much difficulty from freezing and leakage can be avoided by using the method shown in fig. 34. It is usually



DETAIL SHOWING EXPANSION JOINT AND SPECIAL CONSTRUCTION OF TANK FLOOR AND OUTLET

Fig. 34. Pipe expansion joint.

### WATER LEVEL INDICATOR

Every tank should be equipped with a water level indicator and overflow pipe. The customary method used consists of a float on the surface of the water connected by means of a chain to a weighted indicator on the outside wall of the tank (fig. 35). The indicator following a guide shows on a large scale the feet of water. The scale is, of course, reversed as the indicator is at the bottom when the tank

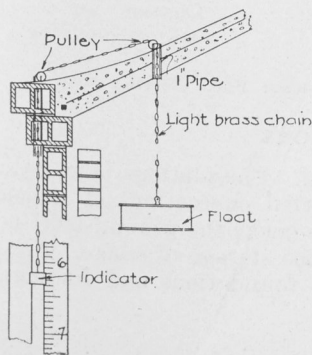


Fig. 35. Water level indicator.

is full. Frost collecting in the pipe through which the chain travels may cause the mechanism to become inoperative.

Another convenient gauge is shown in fig. 36. A device developed in connection with the Whiting tank (fig. 37) consists essentially of a steering column from a Model T Ford car and utilizes the 1:4 planetary gear reduction. The indicator outside travels through only one-half of a revolution while the pulley above the float makes two complete revolutions. This device has proved very satisfactory and has no opening from inside to outside to freeze shut. A pressure gauge located at the ground level will often provide best results.

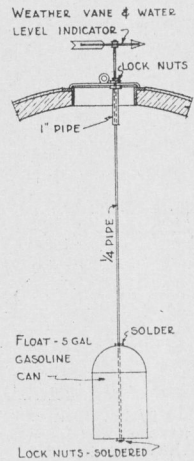


Fig. 36. Another type of water level indicator.

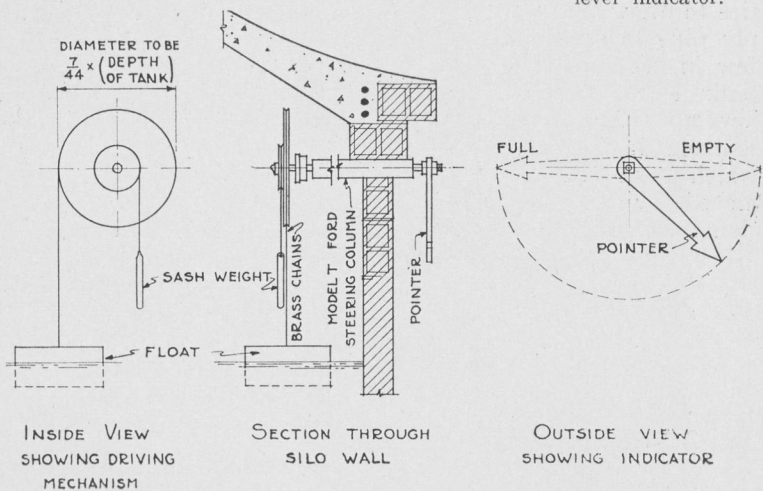


Fig. 37. Water level indicator using Ford steering post.

## FOUNDATIONS

The tank must be well supported. Foundations must extend below the frost line and be supported on footings of sufficient size to prevent settling. The space below the ground level need not be lost but can be utilized for the storage of silage. Fig. 38 shows recommended sizes for both foundations and footings.

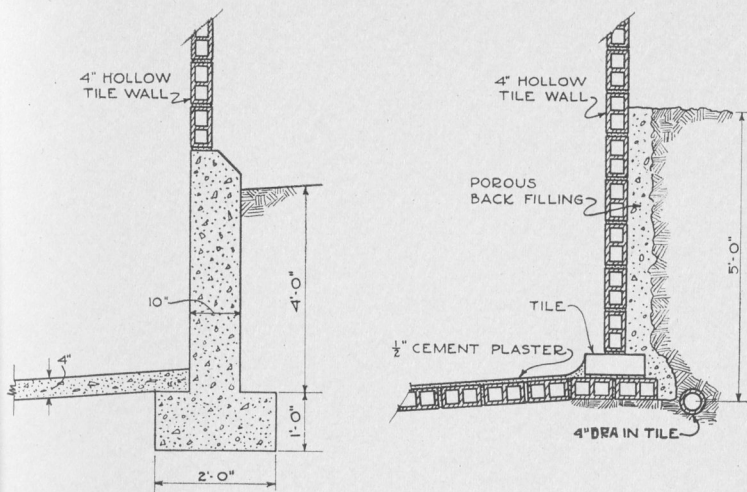


Fig. 38. Design for foundations and footings.